

Satellite/Terrestrial Integrated Mobile Communication System Applicable for Settlement beyond LEO

Yoshiyuki FUJINO

*National Institute of Information and Communications
Technology, Japan*

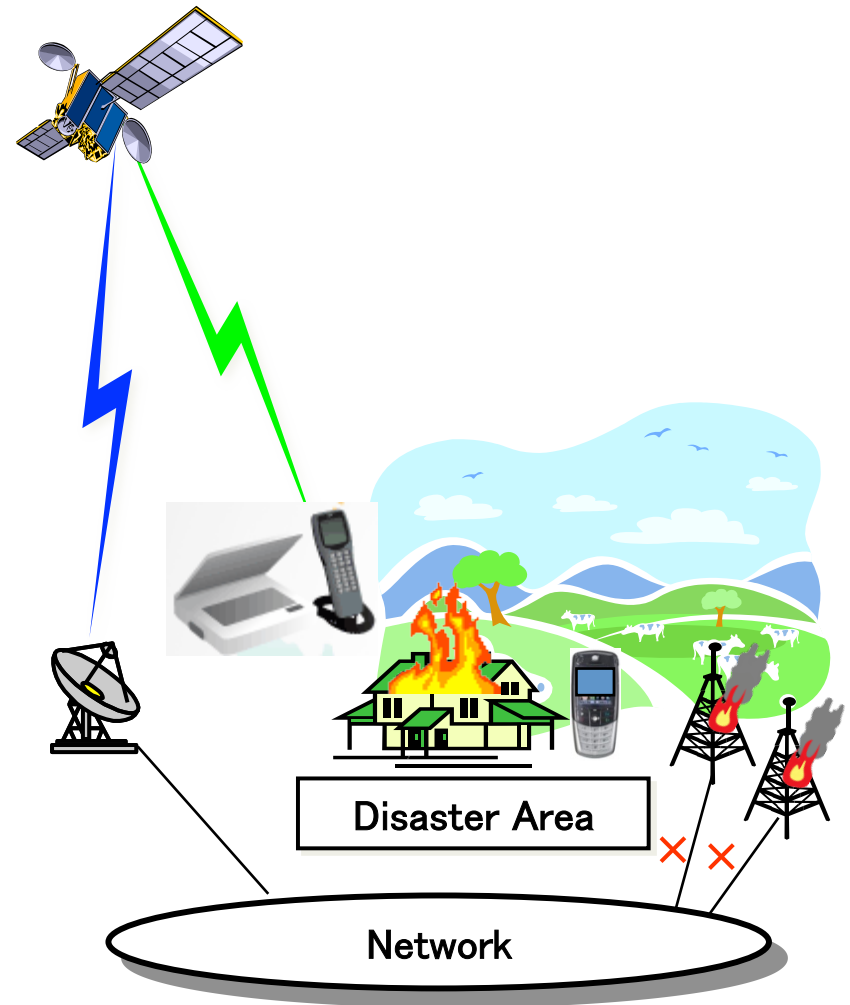
Outline of my talk

- Needs of mobile satellite communication at the time of natural disasters
- Present status of satellite based phone
- Outline of Satellite/Terrestrial Integrated Mobile Communication System
- R&D status of proposed system and intermediate result of F.Y. 2009 & 2010
- Summary

Current state of communication at emergency disaster

Problems

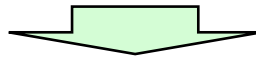
- A public phone net is not connected by crowding at the disaster.
- Due to disaster, base station (BS) damaged and cannot use.
- If it is not a terminal used usually, it is not possible to use it at the national disaster.
- Also, there is a blank of private phone service region in the solitary island, the mountainous district, and the sea, etc.



Needs of mobile satellite communication at the time of natural disasters

Needs

- The satellite communication function is added to the cellular phone that the resident is usually using.
- Mobile communication including picture for disaster measures organization.
- Satellite communication to secure a reliable communication at the crisis.



Miniaturization of satellite communication part and add its function to the ground system cellular phone. Large capacity mobile satellite communication for disaster measures organization.

⇒

- Dual function terminal of the terrestrial system cellular phone and satellite-based mobile phone
- Enlargement of onboard antenna equipped with satellite in S band.
- Development of interference-proof and high output power transponder etc.

Present situation of satellite based phone

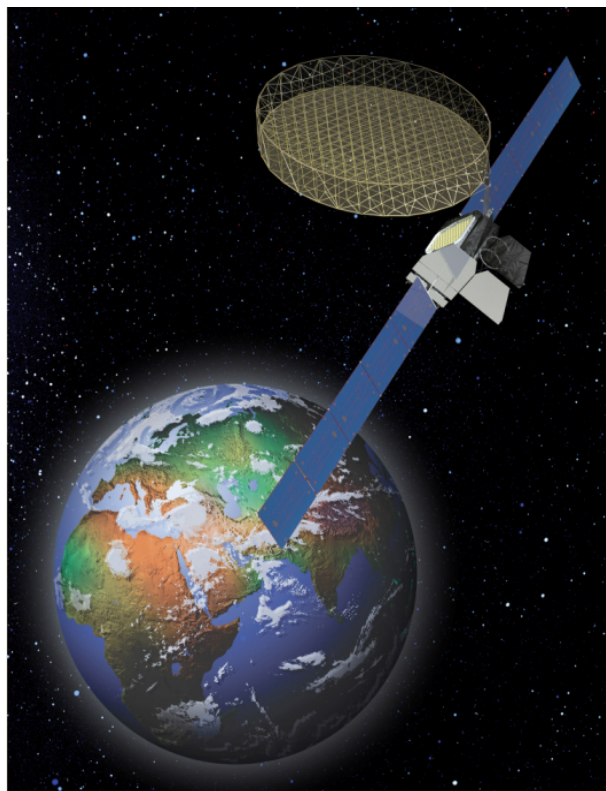
Mobile satellite system using Geostationary orbit (GSO)

- A satellite system which can communicate with portable terminal; Thuraya and ACeS (Garuda)
- Three MSS/ATC system is planning in U.S. which Satellite based phone with cooperation of terrestrial system.
- ATC(Ancillary Terrestrial Component) ; SkyTerra、TerreStar、ICO
- CGC (Complimentary Ground Component) service in Europe; Solaris Mobile, Immarsat, TerreStar-EUR,ICO Global Commemorations; etc

Non GSO Satellite communication system

- Iridium

Thuraya Satellite



Features

- L band deployable antenna with the diameter of 12.25m (Astromesh)
- Number of beam : 100 - 200
- Bandwidth per 1beam : 4MHz
- Onboard digital beam forming network is mounted.
- Thuraya 1-3 are in operation

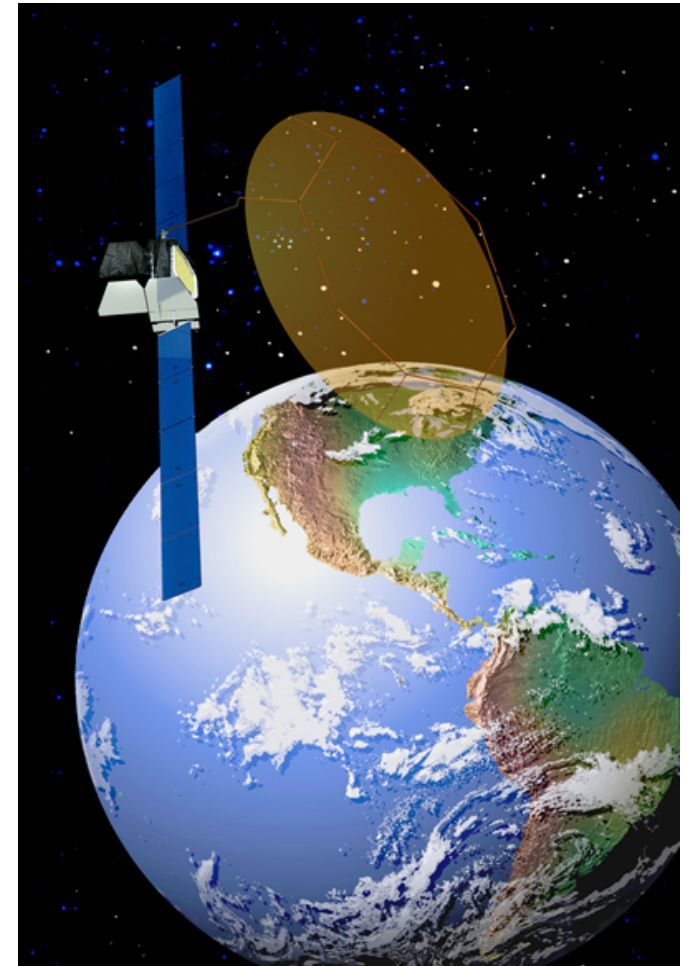
SkyTerra Satellite

Feature

- MSS/ATC Hybrid system in United States.
- L-band deployable antenna : 22m dia. (Harris)
- Service area: Northern and Southern America
- Terminal: Satellite/terrestrial dual mode.
- Feedarray; 82 element, Beam number is about 500 by GBBF

Point of this system

- (1) Low interference from terrestrial system.
- (2) Null beam is generated for strong interference from terrestrial system.
- (3) Beam forming more than 100beam and null beam generation is made by Ground Based Beam Forming
- (4) Multiple feeder link station connected by network

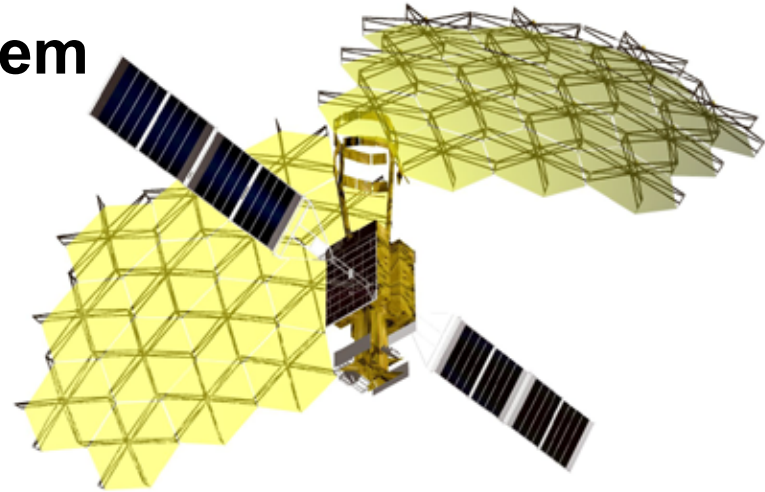


Ancillary Terrestrial Component System in U.S.

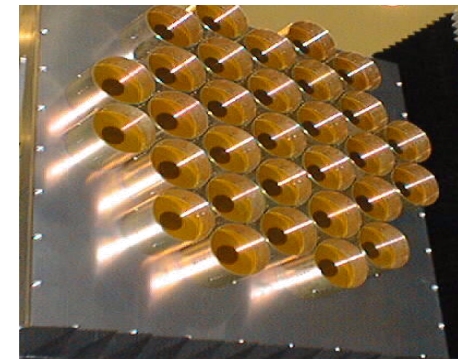
- In the MSS frequency band, Satellite provider used terrestrial system auxiliary. Ground based provider cannot use.
- Frequency commonly use of satellite and terrestrial.
- Required function of ATC
 - Terrestrial service can begin after satellite service begin.
 - ATC is complex service satellite and terrestrial. So, service of terrestrial only is not permitted

ETS-VIII Project

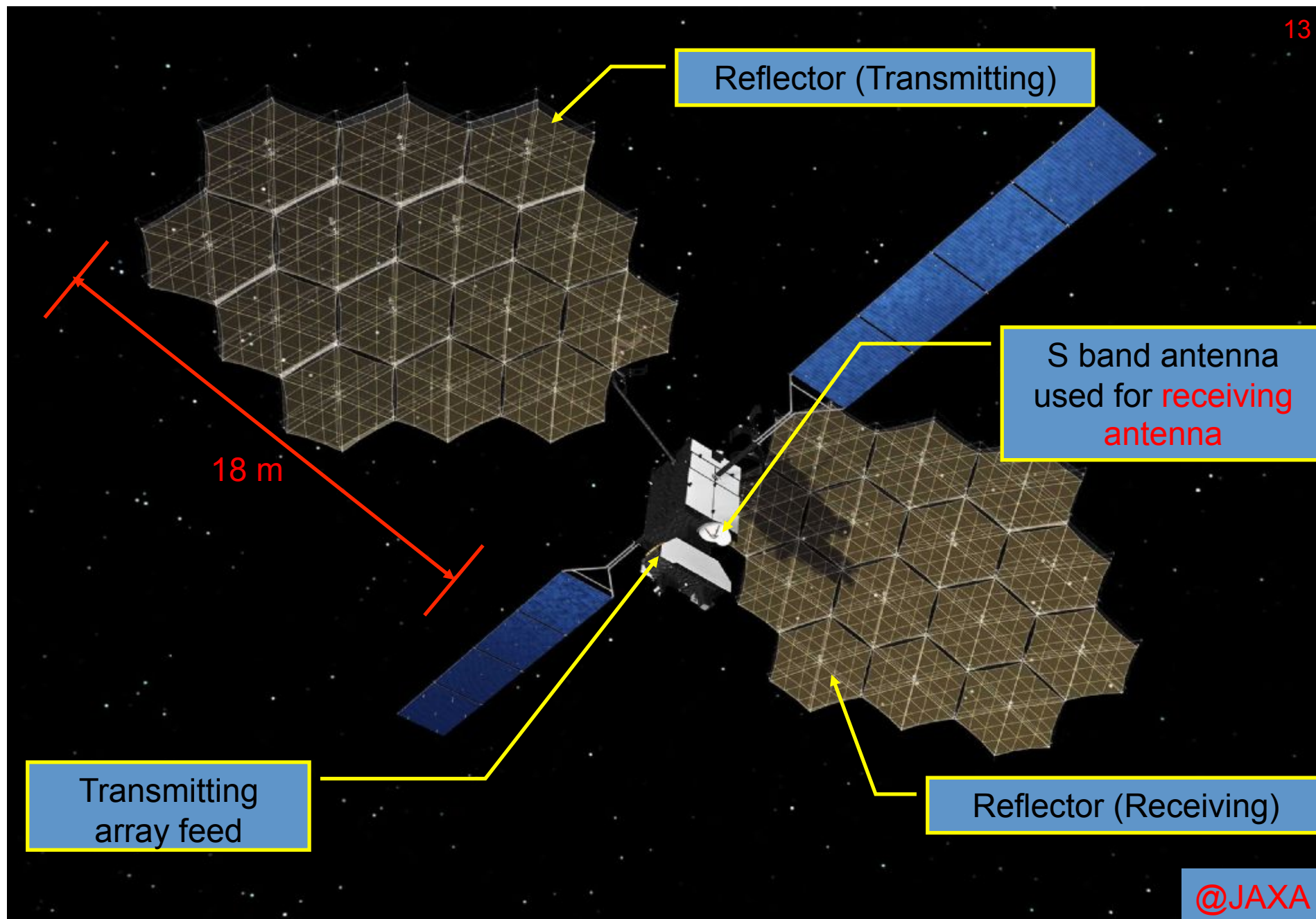
- Experimental system for mobile satellite communication system
- Large deployable reflector antenna (LDR); (19 x 17m)
- Satellite communication experiment using portable terminal
- Launch; Dec., 2006.



Portable terminal; (300g)



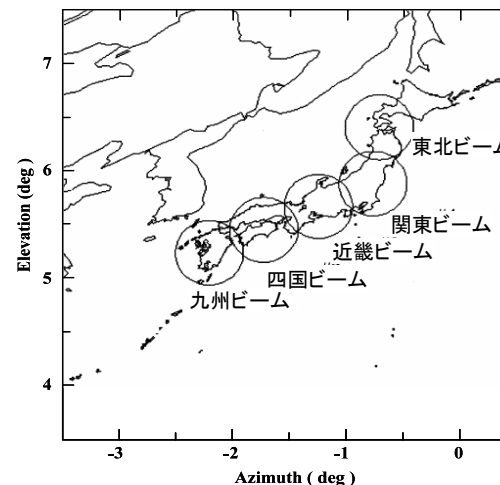
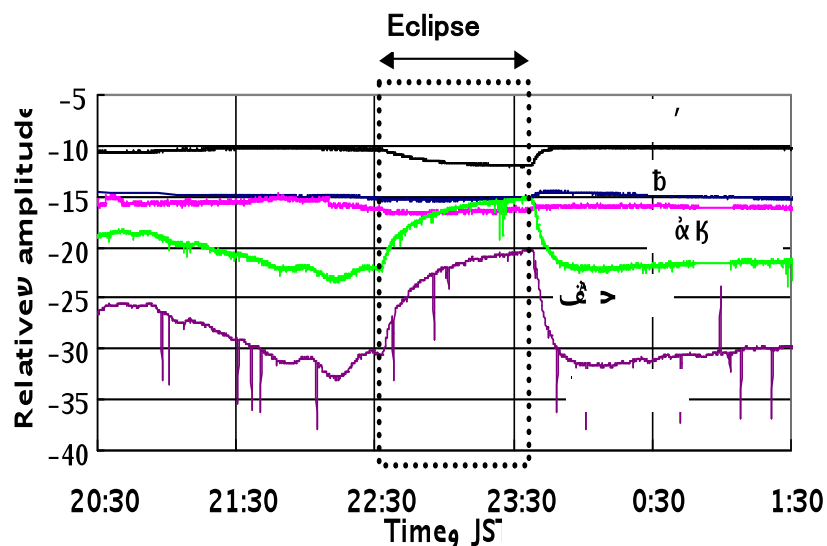
31 elements onboard feeding network



@JAXA

Some result of ETS-VIII project

1. Onboard deploy of LDR is succeeded
2. In LDR beam direction variation of 0.15 deg., at the eclipse is observed. It is because thermal distortion of the reflector.
3. Portable terminal of ETS-8 is demonstrated in the disaster



Portable Terminal

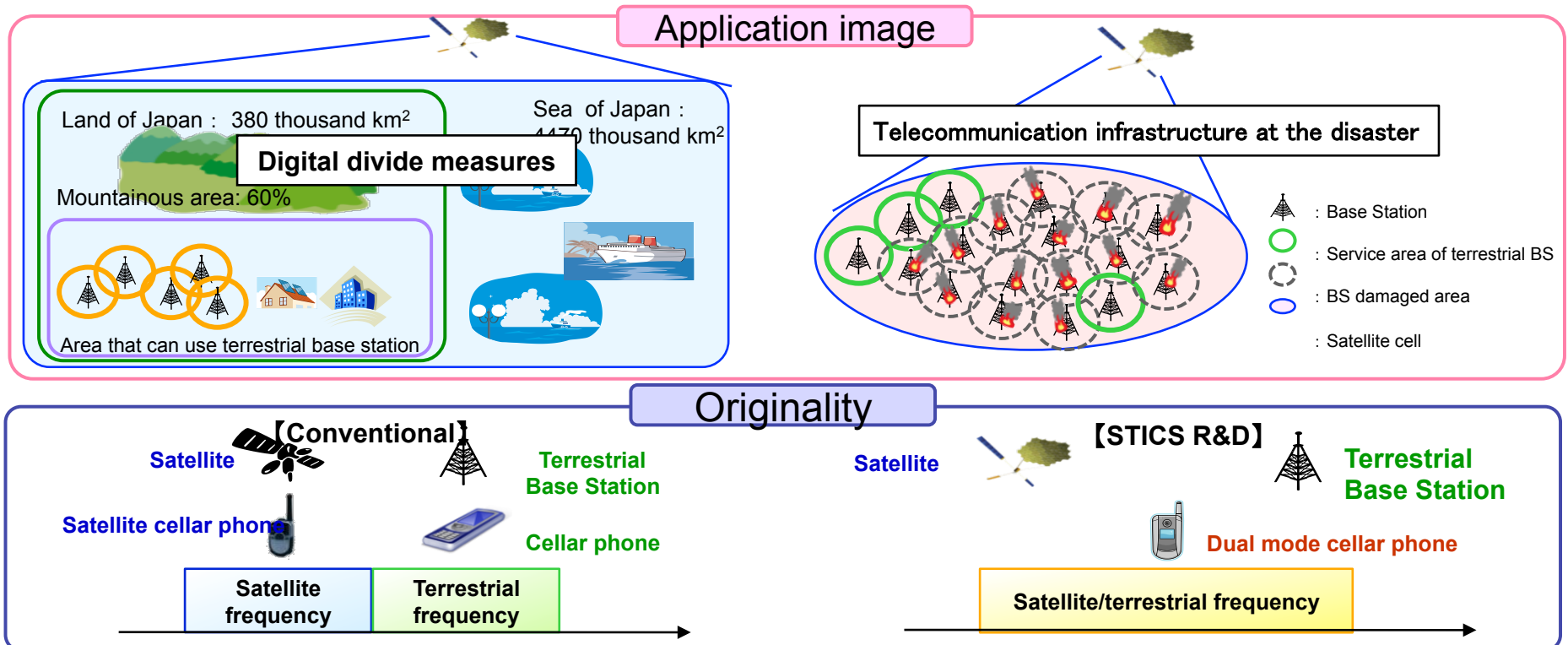
Time variation of receiving level at the eclipse

Demonstration at the disaster prevention exercise

Outline of this research

The technology necessary for the achievement of satellite/terrestrial integrated communication system (STICS) is developing.

This becomes the digital divide measures in no cellular phone zone in the mountains region and the coast region, etc. in normal circumstances. Moreover, it is possible to use as telecommunication infrastructure at the time of disaster.



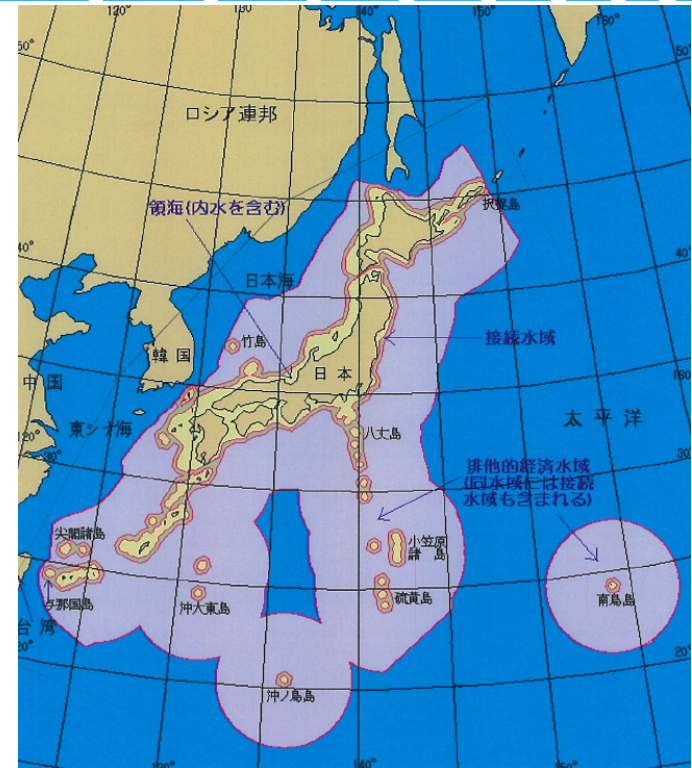
Content of service

Standard service

- Star type service (2 hop), partly small mesh network (1 hop) by service link turning
- Voice communication
 - Speed 10kbps
 - Total channel 5000ch?
- Data communication
 - Speed
 - Portable terminal several k~1Mbps
 - Multipoint TV conference
(Including Data communication)
- Broadcast communication
 - Speed terminal receiving several k~10Mbps

Expand service at the disaster

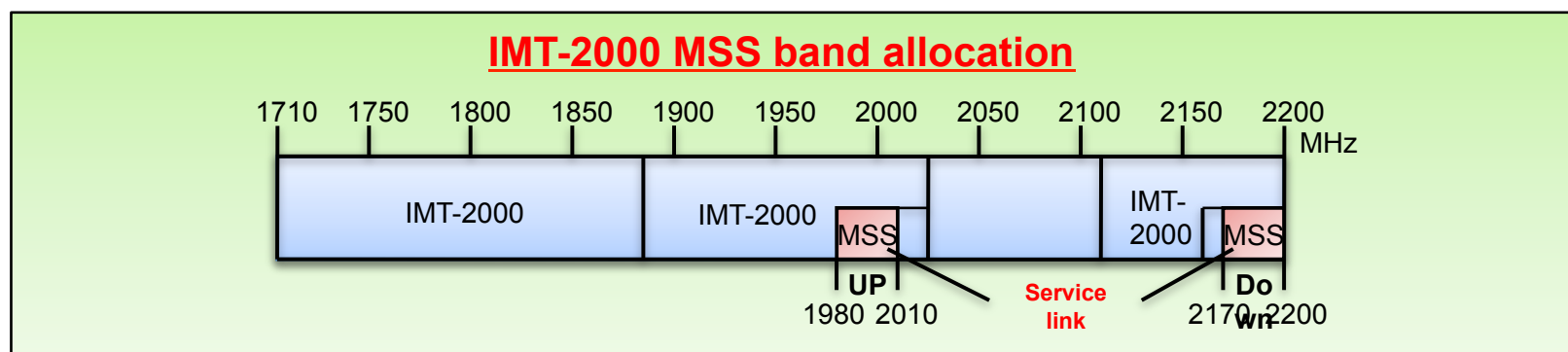
- Traffic control at crowding
 1. Priority service for public organization
 2. Connection restriction of general traffic
- Message (SMS), Broadcast
- GPS



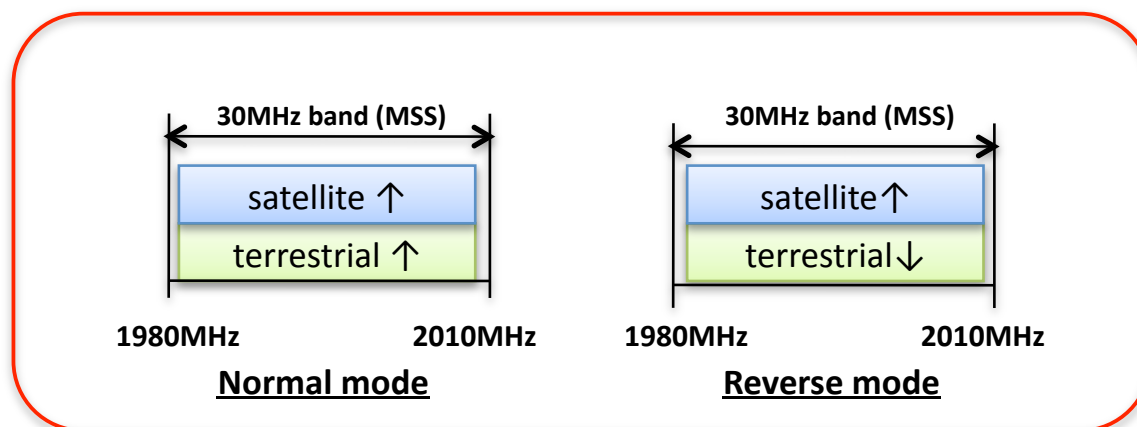
Service Area

- Japanese (main land and solitary island) and EEZ
- Beam flexibility is required for surrounding countries

Frequency sharing technology between satellite and terrestrial use

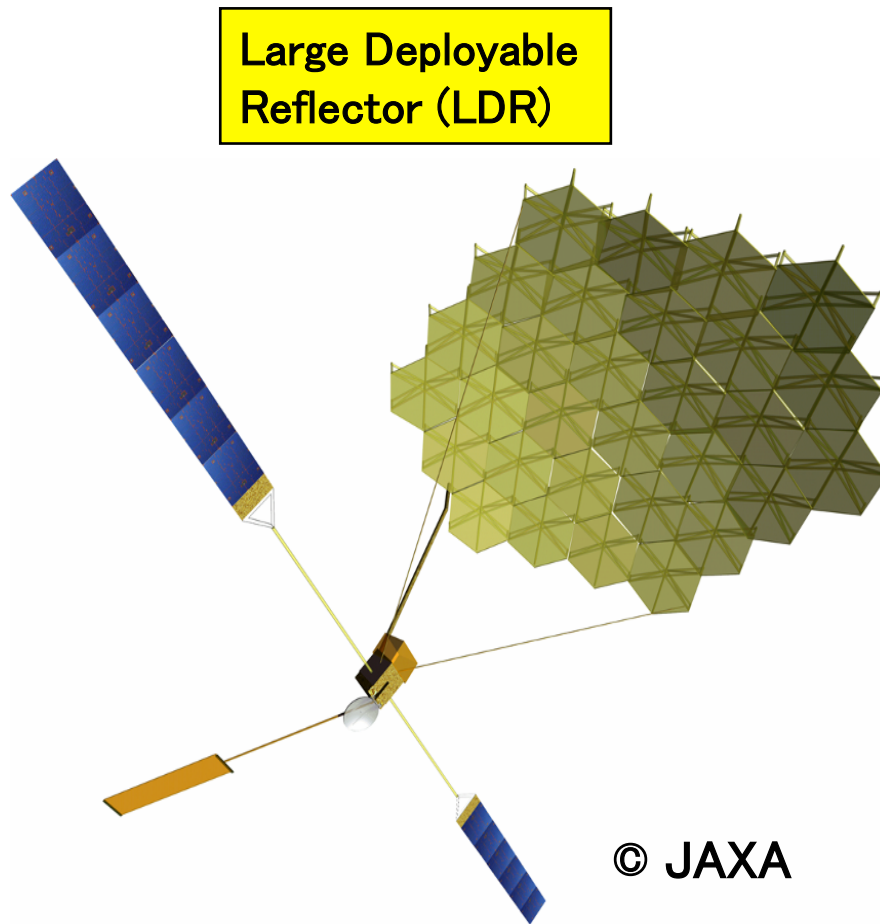


Use MSS allocated band in IMT-2000 which is;
1980~2010MHz(Up), 2170~2200MHz(Down)



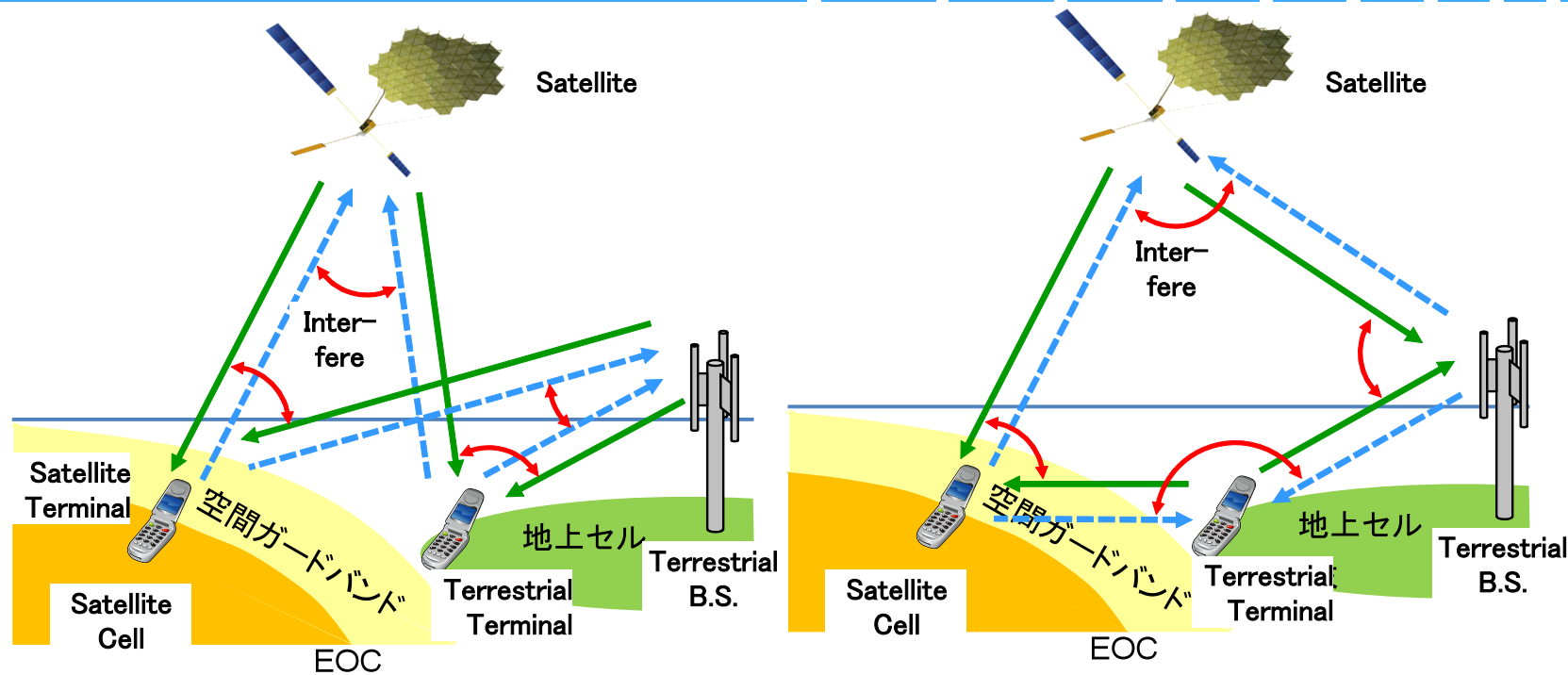
Interference path
is different at
normal /reverse

Assumed antenna specifications for STICS



- Antenna type
 - Offset parabola
 - Phased array feeding
 - Tx/Rx common use
 - Frequency S-band
- LDR
 - Diameter 30m
 - F/D 0.6
- Number of beam
 - About 100
- Number of element
 - About 100
- Beamspot size
 - Around 300km

Interference path in normal and reverse mode



Normal mode

Reverse mode

❑ Interference path in normal and reverse mode is different.

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R&D plan of F.Y. 2009

Satellite/terrestrial cooperation control technology [Term A]

- ◆ The function of the interference evaluation simulator made in FY 2008 is enhanced, and the algorithm to optimize resource such as time, frequency and space is made.
- ◆ The measurement of the transmission output of the ground cellular phone is conducted and evaluated.

Interference avoidance between satellites/terrestrial system and frequency allocation [Term B]

1. and 3. High linearity amplifier technology and super multibeam technology

- A basic part the one Tx/Rx common feeding element is made with diplexer, SSPA and high linearity LNA for a high density antenna feeding circuit.

2. Low sidelobe technology

- The correction technique of the beam direction change that originates from thermal distortion in the reflector is examined, in addition, a basic examination on the sidelobe suppression begins.

4. Reconstruction of resource allocation technology

- Based on the evaluation result for channelizer/DBF computing types, the basic circuit of the channelizer and the DBF is made for trial purposes by using FPGA.

R&D plan of F.Y. 2010

Satellite/terrestrial cooperation control technology [Term A]

- ◆ Surveillance and control simulator equipment of the terrestrial system traffic (number of terrestrial system users) and satellite system traffic (number of satellite system users) is developed. Interference in the situation in which traffic changes is evaluated by this simulator.
- ◆ The measurement of the transmission output of the ground cellular phone is conducted and evaluated.

Interference avoidance between satellites/terrestrial system and frequency allocation [Term B]

2. Low sidelobe technology

- The excitation amplitude phase weight to decrease sidelobe level is examined. Moreover, the technology that forms the null in a specific area is examined and the verification experiment of the low sidelobe technology is executed.

3. Super multibeam technology

- Small scale prototype production of feeding network for confirmation of beam generation is proceeded.

4. Reconstruction of resource allocation technology

- Small scale prototype production of channlizer / DBF equipment and frequency conversion unit connecting digital part and analog part.

Interference evaluation simulator

➤ Evaluate STICS Interference based on power calculation

Simulation model setup

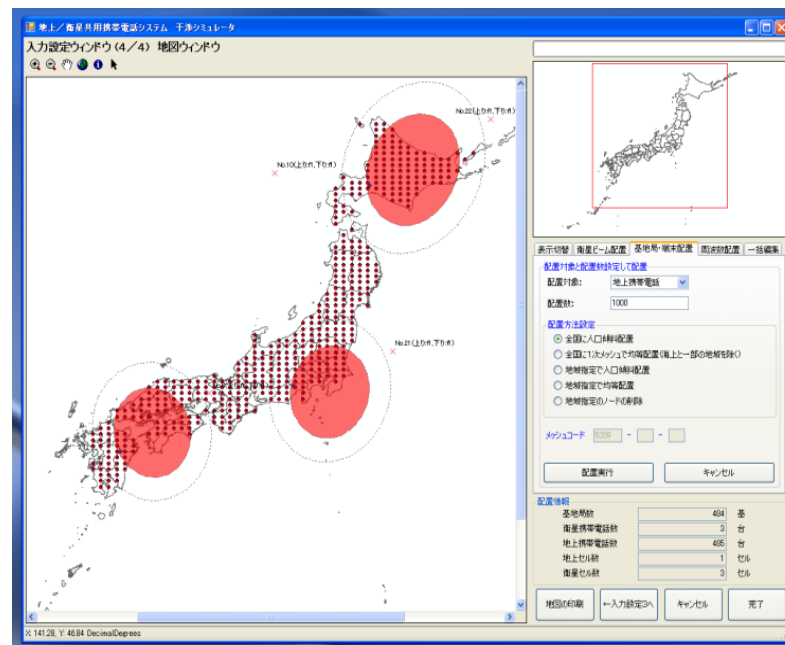
- Beam shape / arrangement
- Terminal arrange/ frequency arrange/ output power
- Width of spatial guard band; etc

Analysis execution

- Extract all interference source
- Interference calculation of desired channel etc.

Confirmation of analysis

- Interference
- Antenna pattern; etc



The screenshot shows the '衛星システム出力 衛星受信干渉電力' (Satellite System Output Satellite Reception Interference Power) window. It displays a table of interference power values for various satellite terminals.

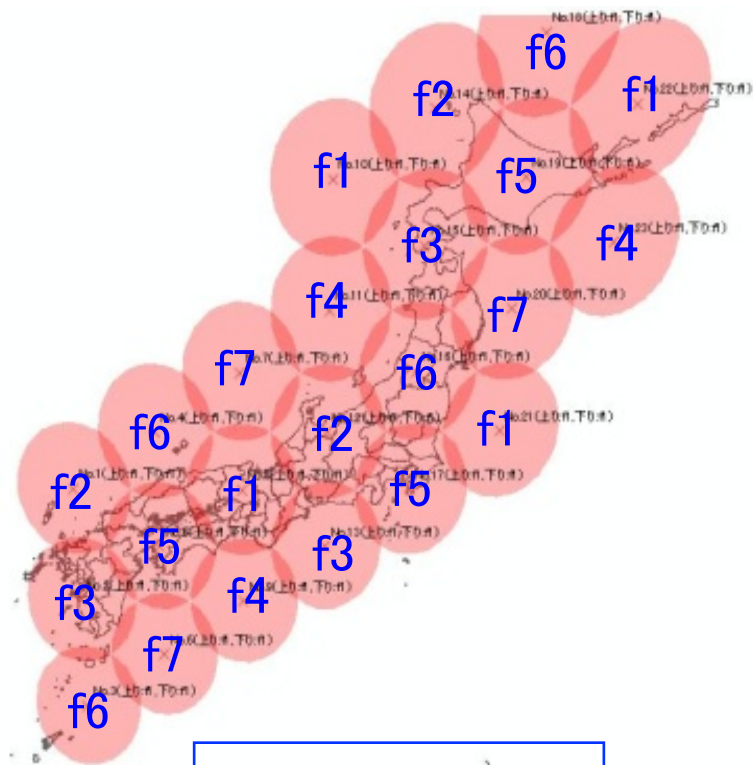
地上端末No	基地局No	干渉電力[dBm]
2	2	-168.13
3	3	-164.93
5	5	-166.11
6	6	-163.32
8	8	-164.53
9	9	干渉なし
13	13	干渉なし
16	16	干渉なし
19	19	-166.47
20	20	-163.27
21	21	干渉なし
22	22	-165.20
23	23	-162.26
24	24	干渉なし
27	27	干渉なし
28	28	干渉なし
29	29	干渉なし
31	31	干渉なし
32	32	干渉なし

Simulation flow

Model setup of simulator

Check of result

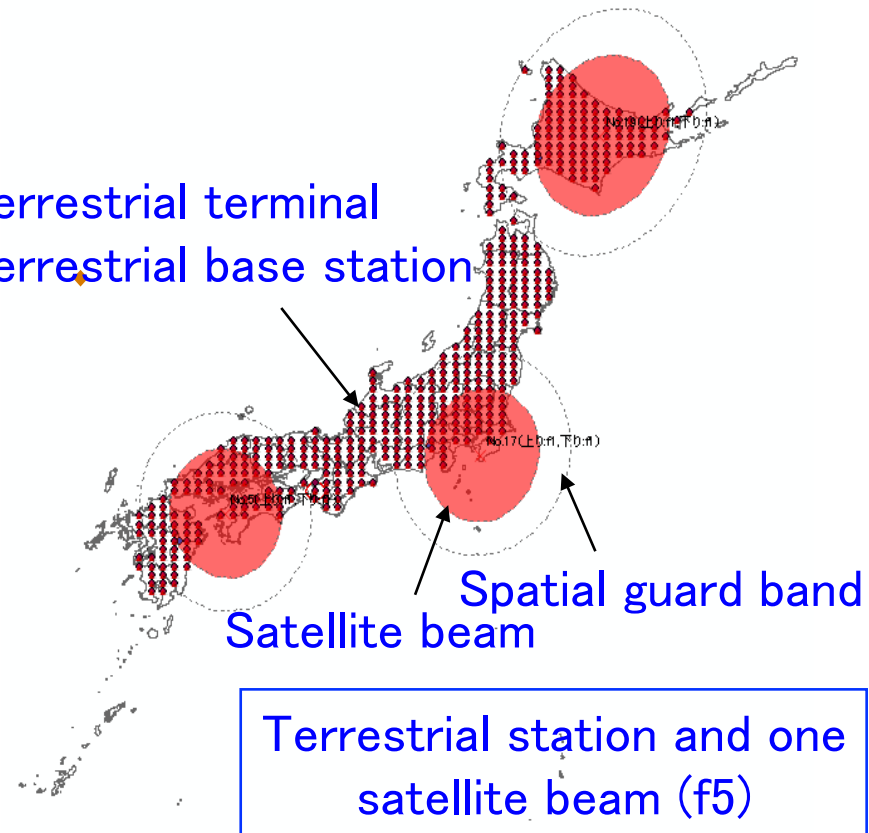
Allocation of satellite beam (example) ...



Allocation of satellite beam

23 beam covers in the main land of Japan with 7 frequencies

Terrestrial terminal
Terrestrial base station

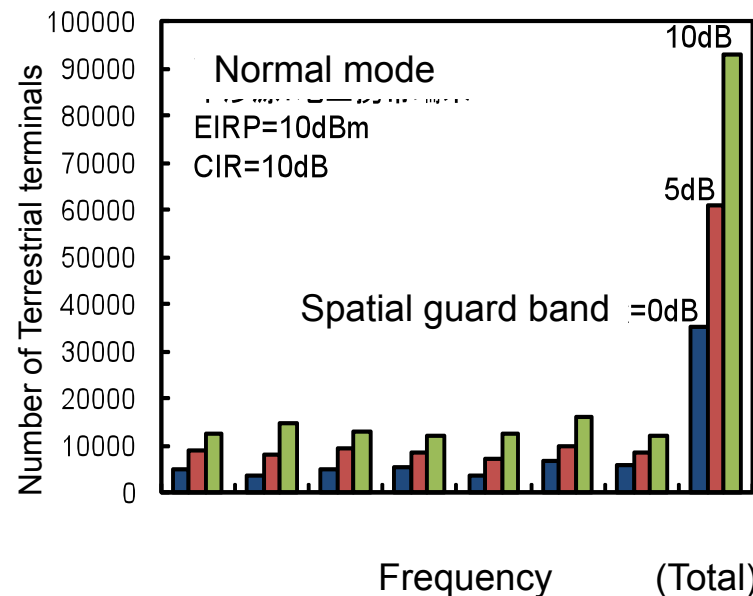
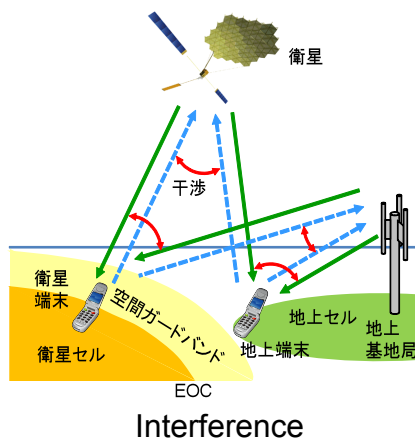


Japan mainland, uniformly distributed same number of terrestrial terminal and terrestrial stations

Primary result from the interference evaluation simulator

□ Satellite uplink interference from ground mobile terminal is calculated. System capacity was estimated .

(1) Evaluate condition; allocation and output power was uniform



System capacity

C/I Terrestrial terminal EIRP	10dB	20dB
0dBm	90 million	9 million
10dBm	9 million	0.9 million

*Spatial guard band 10dB

*7Frequency colors

*Simultaneous call rate=1%

Result

□ System capacity becomes 90 million in maximum

Transmitting power measurement of terrestrial cellular phone

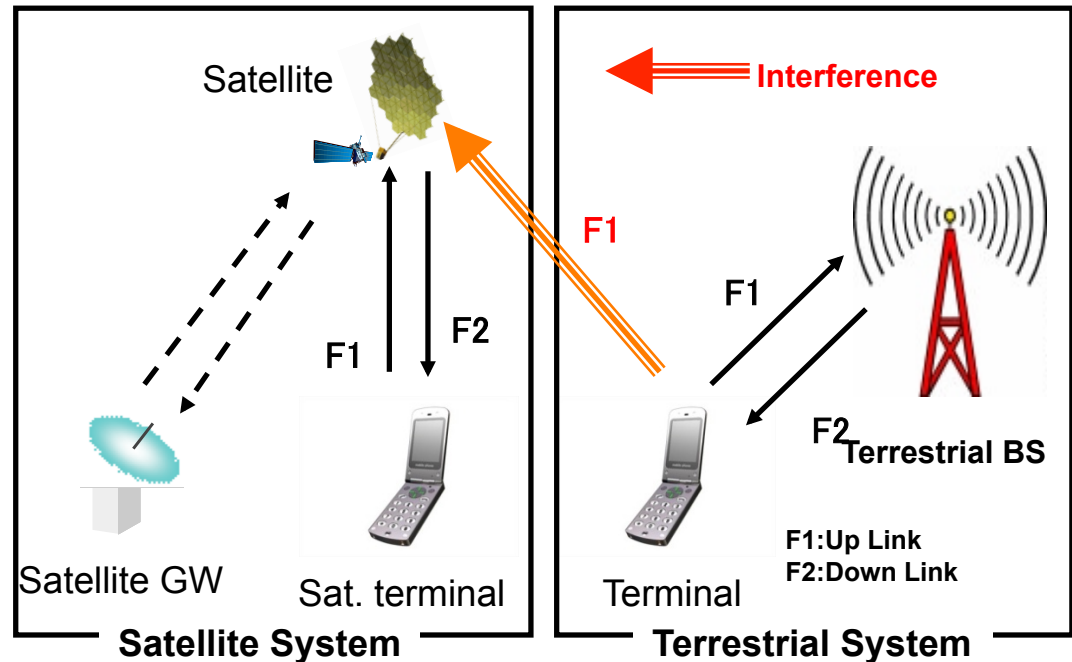
- Interference from terrestrial system to satellite system is worried.



- Evaluation of the interference level becomes important point of this system.



- To get the reference data for interference level, output power of cellular phone is measured.



STICS Interference route

- Experiment example by SkyTerra (former MSV) co. in the United States (CDMA2000)

Average transmission power of cellular phone.	Dense Urban	Urban	Suburban
	-12.9 dBm	-6.4 dBm	-1.3 dBm

Transmitting power measurement of terrestrial cellular phone

Transmitting power measurement experiment

Various condition was assumed using ground vehicle and airship.

Measurement using ground vehicle

Result

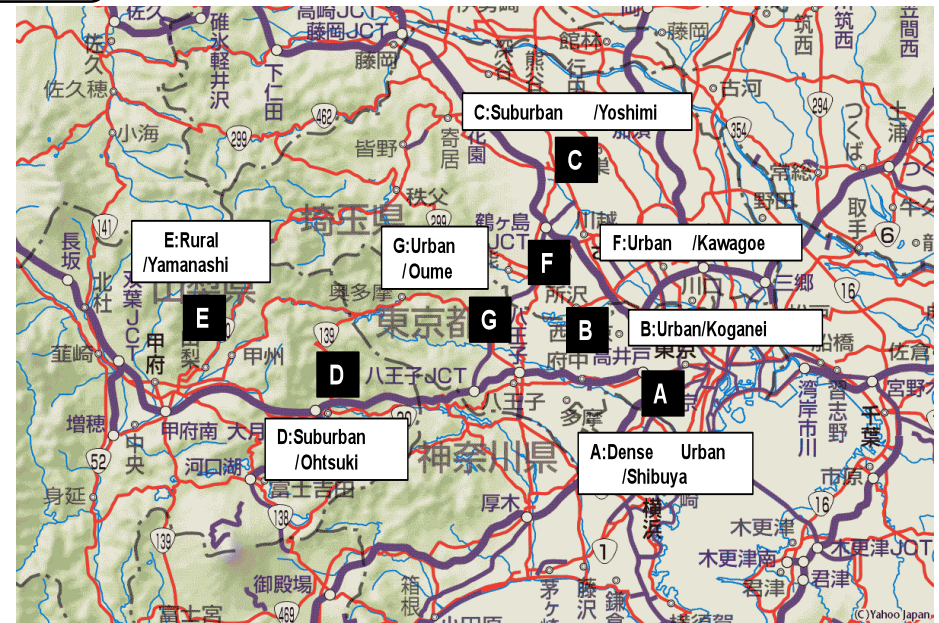
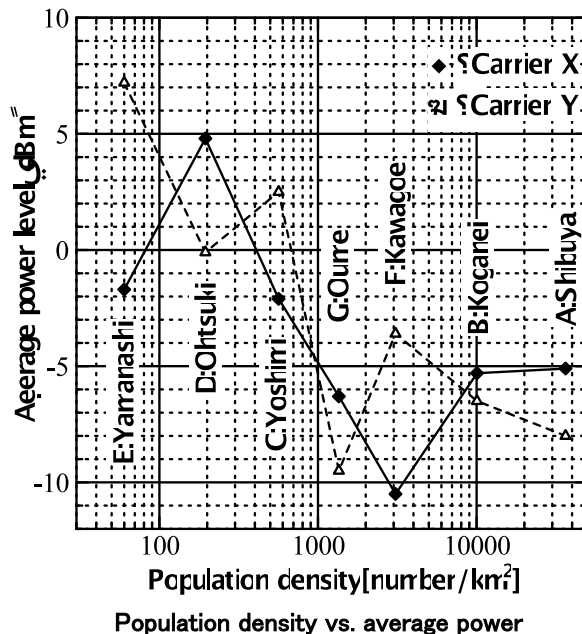
- In urban area, output power was less than -5dBm . Reference data of interference is acquired.



Measurement car



Antenna with phantom



Measurement areas (7 area)

Transmitting power measurement of terrestrial cellular phone

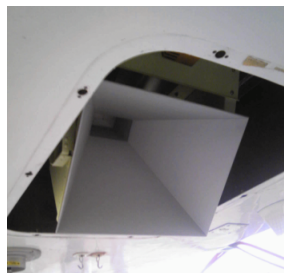
Mesurement using airship

Result

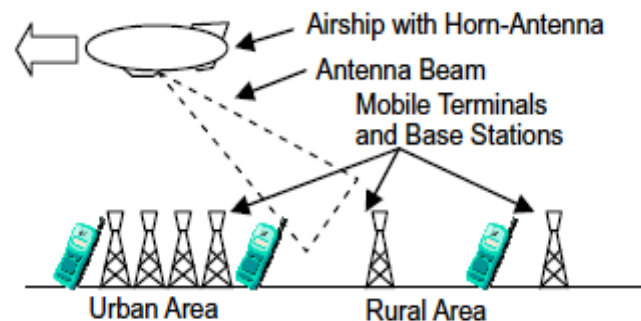
- As a result of airship measurement;
- Receiving level from Mobile Terminal was 25–30dB lower than receiving level from Base Stations.
- Normal mode has advantage rather than Reverse mode.



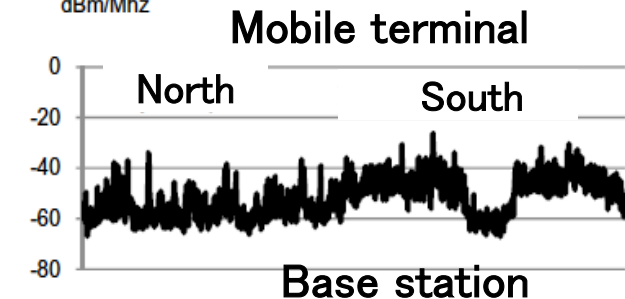
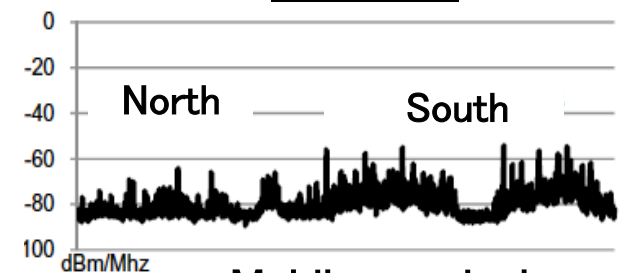
Mesurment route



Airship and antenna



Mesurement method

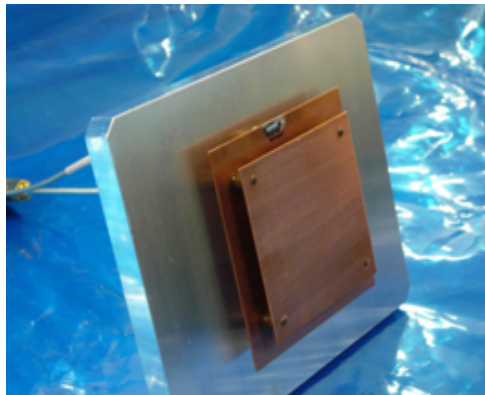


Time vs. Receiving level

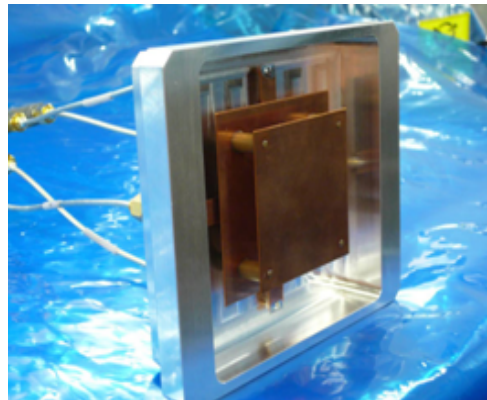
Super multibeam technology

Trial production of radiation element for transmitting and reception

1. For high density phased array element with Tx/Rx dual mode, we tried to feasibility study with a point of size, gain, axial ratio, Tx/Rx isolation. And (a) patch antenna with parasitic element, (b) patch antenna with cavity and parasitic element and (c) Self diplexing antenna are trial production.
2. (b) shows best performance. So, we selected this for the candidate.



(a) Patch antenna with parasitic element



(b) Patch antenna with cavity and parasitic element



(c) Self diplexing antenna

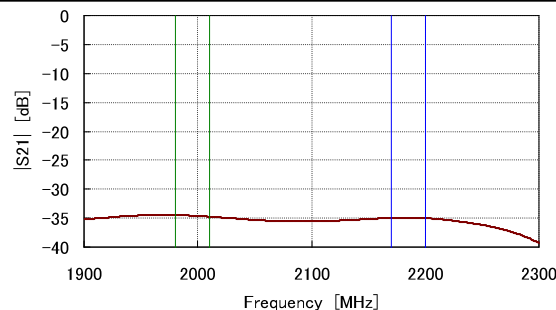
Super multibeam technology

Trial production of feeding part for Tx/Rx

Trial production of radiation element and diplexer

Result

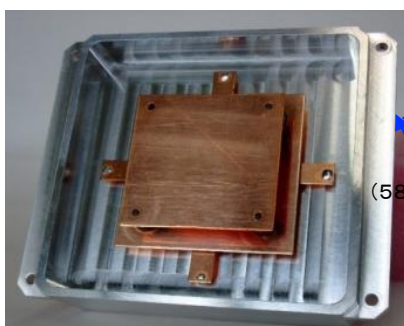
- Interelement coupling shows good result of -34dB.
- Volume of diplexer becomes half of conventional model
- ✓ Production of 16-elements array and light weight diplexer is problem for FY. 2010)



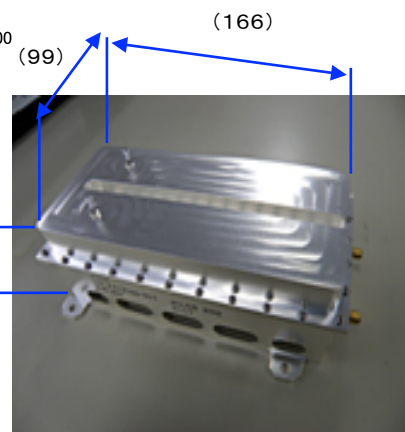
Interelement coupling



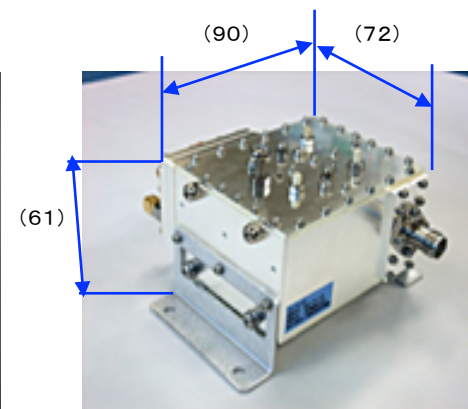
Cavity backed patch antenna with parasitic element



(58)



Trial product of diplexer (FY. 2008)



Trial product of diplexer (FY. 2009)

Unit in mm

Low sidelobe technology

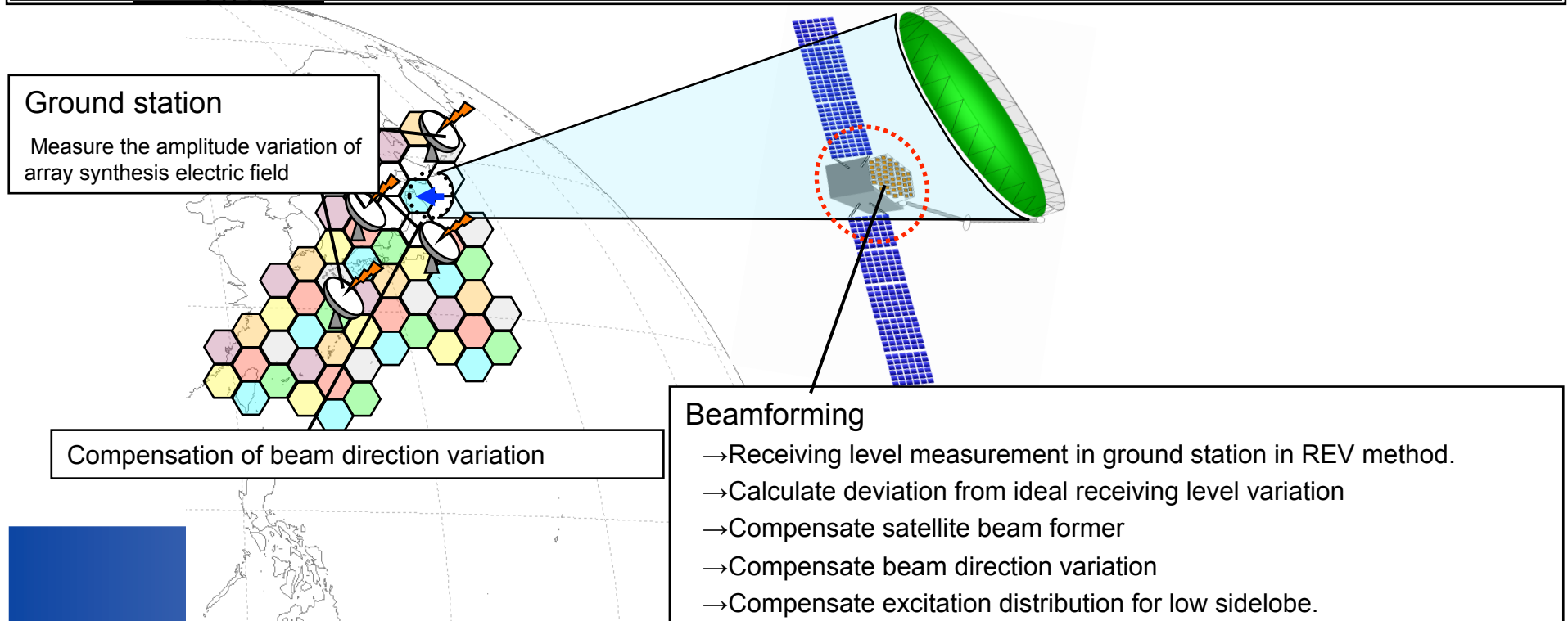
The correction technique of the beam direction change that originates from thermal distortion in the reflector
Simulation software for beam direction variation in satellite mounted large scale deployable antenna

① Detect excitation amplitude and phase distribution of each antenna element.

Detection method: Rotating Element Vector (REV) method; Measure the receiving amplitude variation of array synthesis electric field at ground station and calculate amplitude and phase of each antenna element.

② Compensation method

Compensation of beam direction variation will be simulated by result of REV method in multiple (two or more) ground.

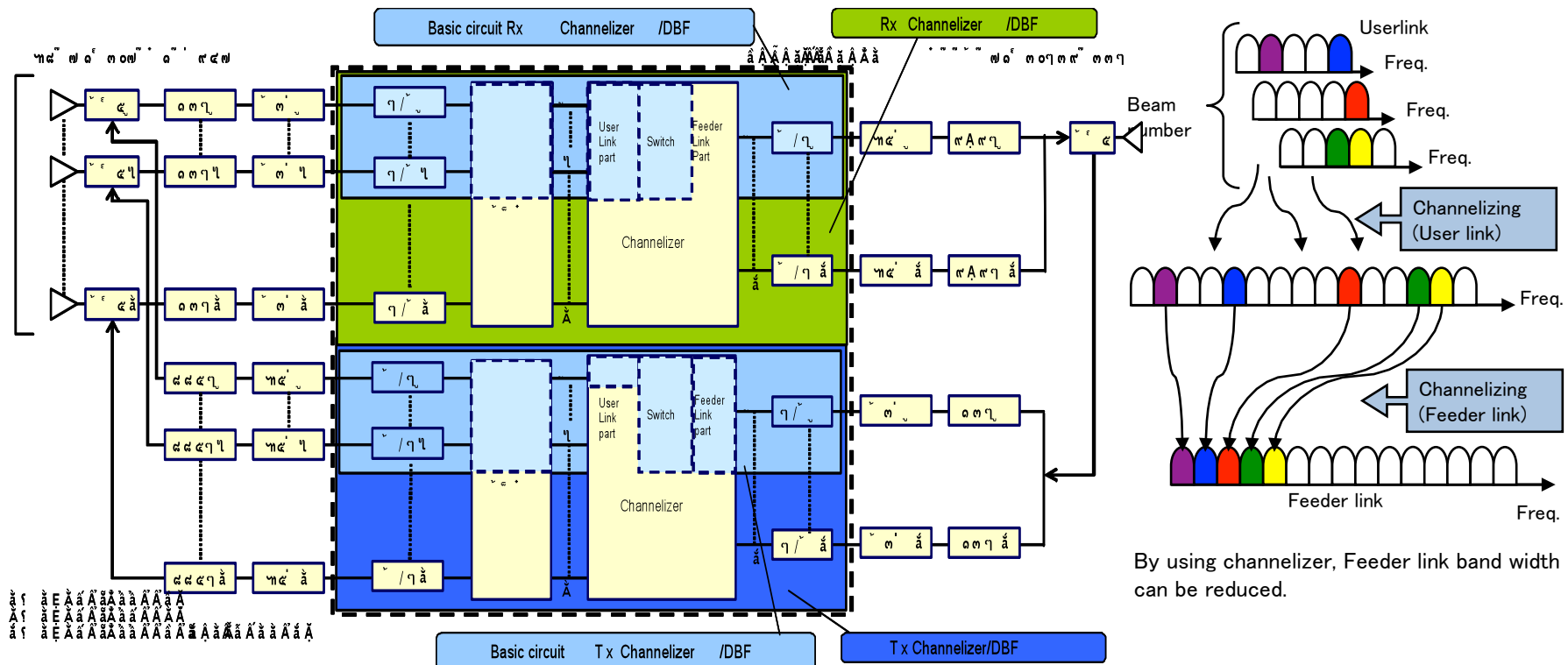


Reconstruction of resource allocation technology

Trial production of basic circuit of the channelizer and the DBF

Result

- Trial production of basic circuit of the channelizer and the DBF in hardware.
- 8 elements and 8 beams
- ✓ 16 elements 16 beams the channelizer and the DBF (FY2010)

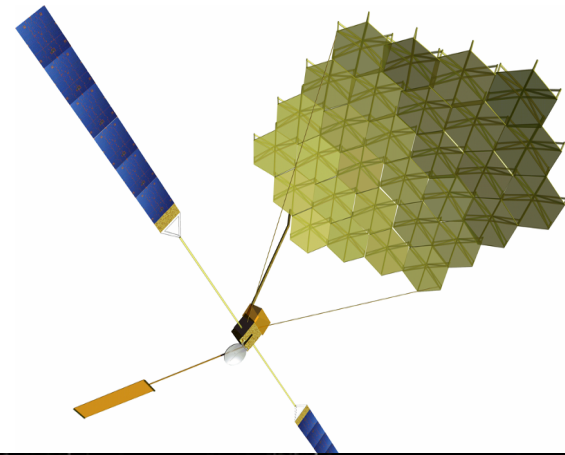
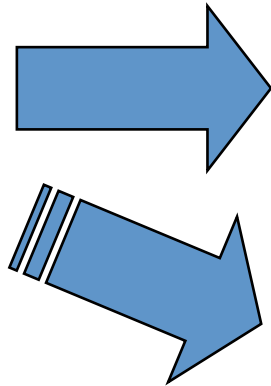
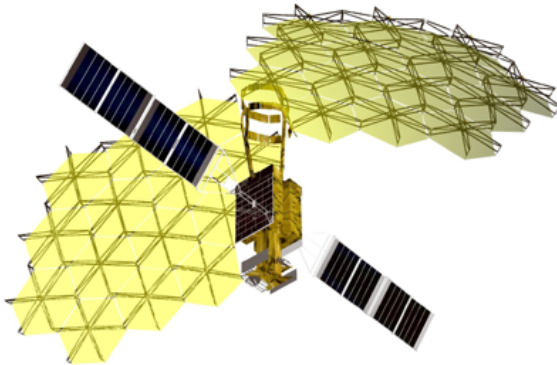


Summary

Outline of Satellite/Terrestrial Integrated Mobile Communication System for measures to deal with natural calamities is explained.

R&D plan, each R&D items and intermediate result in F.Y. 2009 and F.Y. 2010 are introduced.

Space Based Large Structure Antenna



- Space based large scale antenna knowledge such as thermal distortion can be applied not only future communication satellite but also applied to Space based Solar Power Satellite.
- NICT continues research of such antennas.

